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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

COMPACT CARS

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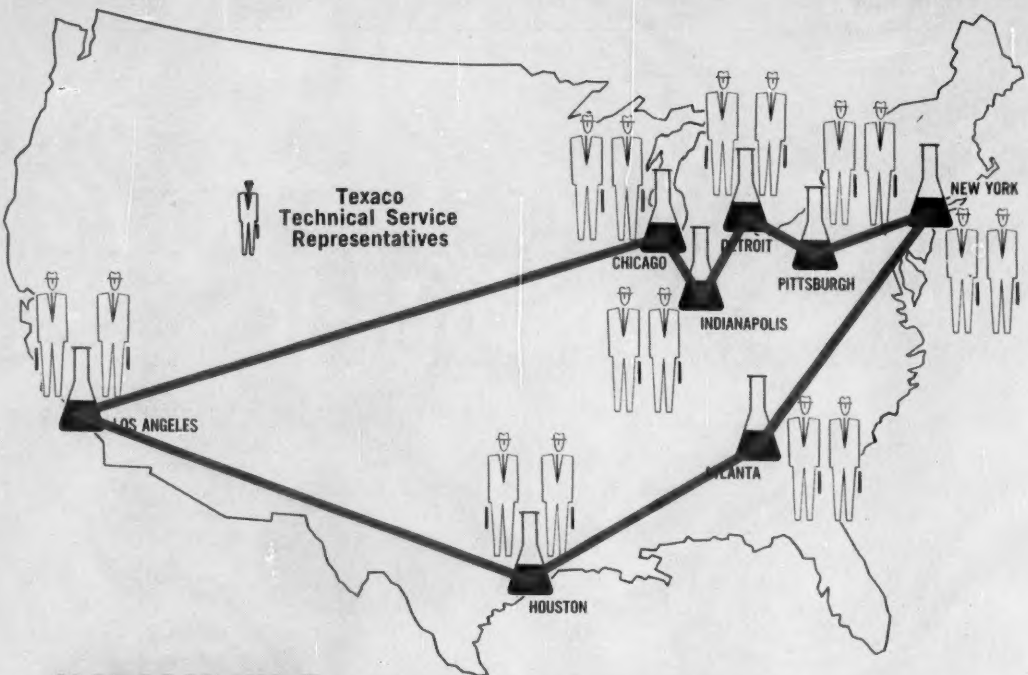

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COMPACT CARS

THIS article will discuss the design features and lubrication requirements of the American Compact Cars. However before undertaking such a discussion a brief survey of the history of the development of these automobiles might be in order. With the recent introduction of the so-called "small" or "compact" car by the major automotive manufacturers, it is a widely held misconception that the U. S. built compact cars are new to the American scene. American automotive history will show that this is not the case. Between the early 1930's and 1959 there were no less than seven different compact cars manufactured. Among these were the American Austin (1930), the American Bantam (1937), The Crosley (1941-48), The Willys Americar (1941), the Henry J (1950-51), the Hudson Jet (1953-54) and of course the compact Plymouth Wayfarer which was offered briefly in 1949 and 1950. Aside from these public presentations, several manufacturers have designed compact cars and brought them to the prototype stage. Chrysler reached this point during the early 1930's as did Chevrolet during the latter part of that decade.

While much has been written regarding the reasons for the present acceptance of the compacts, little has been said regarding their previous failures. Obviously, previous market conditions were not "right". The contributing factors to this condition of "rightness" are lodged in our previous economy and living habits. During the early '30's the present trend to "suburbia" had not yet materialized and public transportation was adequate to handle the daily chores of commuting, shopping, etc. The community was compact and to many, personal transportation was a luxury. While many of these factors began to change after World War II, the demand for automobiles ran so far ahead of the supply that almost any kind of a new car could be sold. Economy of operation, size, handling ease, etc. were not dominant factors in determining public acceptance.

This situation was prolonged by the Korean conflict. Finally however, as a result of a "bumper" selling year in 1955, supply did catch up with customer demand. This resulted in a gradual reappraisal by an ever increasing portion of the buying public of what an automobile meant to them individually. Also by 1955 the trend to suburbia was well advanced. Public transportation was unable to economically meet the challenge of the changed travel and, as a result, more people were using the automobile as a means of personal transportation. In fact to many, a car had ceased to become a luxury since it was the sole means of transportation to and from work or shopping. As a result of this increased use of personal transportation, traffic and parking problems became more acute and many found that a small car could serve just as well as a large one. This type of thinking started to manifest itself in 1956 when the first real upswing in the sale of the compact American car, Rambler, and of foreign cars became apparent.

As more and more people became acquainted with

TABLE I
GENERAL SPECIFICATIONS

Manufacturer and Make	Wheel Base (Inches)	Length Over-all (Inches)	Width Over-all (Inches)	Curb Weight (Lbs) (4 Dr Sedan)	Weight Distribution Front/Rear (%)	Tire Size (Std.)	Tire Inflation Press. Cold Front/Rear (PSI)
American Motors Corp.							
Rambler-6	108.0	189.5	72.2	3038	54.5/45.5	6.40 x 15	24/24
Rambler Rebel V-8	108.0	189.5	72.2	3402	56.9/43.1	7.50 x 14	24/24
Rambler American	100.0	178.3	73.0	2614	53.0/47.0	5.90 x 15	24/24
Chevrolet Motor Div., GMC							
Corvair	108.0	180.0	66.9	2375	37.5/62.5	6.50 x 13	15/26
Chrysler Corp.							
Valiant	106.5	183.7	70.0	2725	55.2/44.8	6.50 x 13	24/24
Ford Motor Company							
Comet	114.0	194.9	70.4	2540	52.5/47.5	6.00 x 13	24/24
Falcon	109.5	181.2	70.0	2395	53.7/46.3	6.00 x 13	24/24
Studebaker-Packard Corp.							
Lark VI	108.5	175.0	71.4	2732	53.7/46.3	5.90 x 15	24/20
Lark VIII	108.5	175.0	71.4	3091	58.4/41.6	6.40 x 15	24/20

the smaller cars, the economic factors of operating costs, overhead, depreciation, etc. also began to receive attention thus adding further impetus to the trend. This economic evaluation was accelerated by the fact that State and Federal gasoline taxes were rising to the point where they were almost one-third of the gasoline dollar (a tax rate of almost 50 per cent). This trend towards smaller cars gained such impetus that by the end of 1959, the total sale of the American compact and imported cars amounted to slightly more than 15 per cent of all cars sold in the United States.

Nash (before the merger with Hudson which created American Motors) was the first to benefit from this trend. While Nash had introduced a compact car, the Rambler, in 1950, its sales were unspectacular. However, in 1955, this car was redesigned in its present form in time to take advantage of the full effect of the change in public thinking regarding compact automobiles.

Studebaker was next to move in this direction with the introduction of the Lark which was fitted with either an in-line six or a V-8 engine. This car was also greeted with enthusiasm and did much to spark the present entrance of the "Big Three" into this field. During the Fall of 1959 and early Spring of 1960 the latest of the compacts manufactured by Chevrolet, Chrysler and Ford were introduced. Initial sales figures indicate that these offerings will also be well received by the American public. The effect of these latest offerings on the sale of foreign cars has not yet been determined. However, it appears that compacts are here to stay since even more entries are being planned. General specifications of these cars are shown in Table I.

ENGINE

While the foregoing review of the history of the compacts is of interest, the purpose of this article is to discuss the design features and the lubrication requirements of these cars. We will begin our discussion with an examination of the design criteria which were considered significant and helped establish the various engine design features. This appears to be a logical point at which to start since it is here that the energy in gasoline is converted to useful work and it is thus the starting point in the "drive train".

Design Criteria

Before discussing specific design features of the compact car engines it might be well to orient the reader with regard to what was actually desired in these engines. Obviously the major criterion was economy of operation as measured by gasoline mileage. This characteristic, while important, could not completely dominate design decisions since, for sales reasons, it was desirable to maintain a reasonable car performance in terms of acceleration and top speed. While it may be superfluous, it must be recognized that, with a given car design and weight, as the gas mileage or economy is increased, the car performance will decrease. Therefore, for these reasons a compromise was reached so as to have gaso-

line economy better than 22 miles per gallon of gasoline and a reasonable performance in terms of top speed and acceleration.

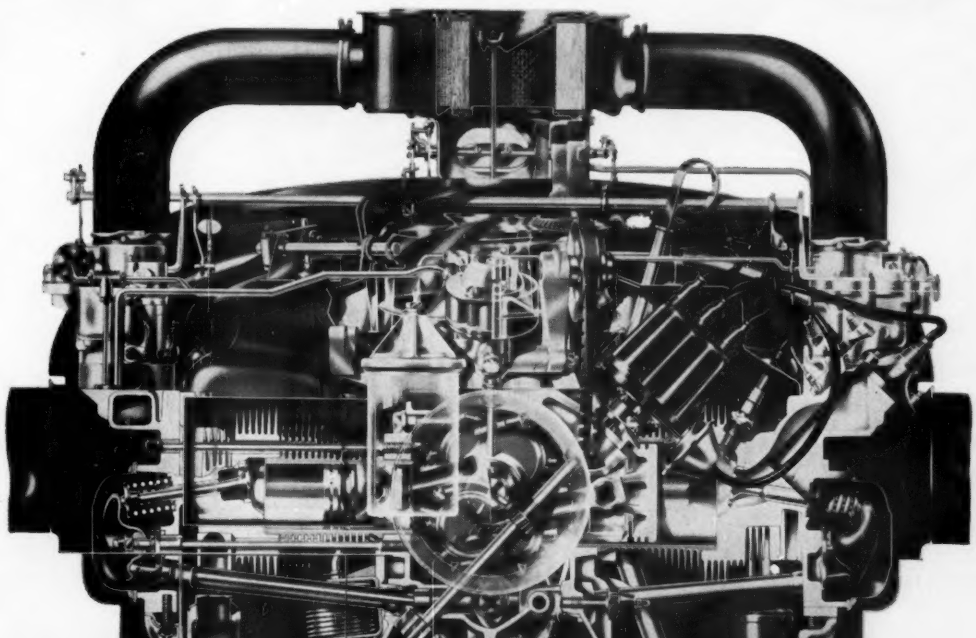
To achieve this compromise, a decision also had to be made as to the type of engine which would be used whether it would be a four, six or eight cylinder engine and its arrangement whether in-line, "V" or horizontal. It was recognized that the interests of economy could be best served by using a four cylinder engine. However it was felt that the use of this type of power plant would inhibit the acceptance of a new American automobile. Therefore although it was considered, no American manufacturer used this approach, preferring the slightly increased cost and weight penalties associated with a six cylinder design in order to obtain a greater degree of engine smoothness. However, there are two exceptions to this pattern. They are the Rambler Rebel and the Lark VIII, both of which are equipped with V-8 engines. Since these engines have somewhat greater displacements[1] than the six cylinder engines normally used in the compacts, they do add appreciably to the car performance although tending to reduce the gasoline economy measured in miles per gallon. It is interesting to note that while these more powerful engines are available in the compact car field, they do not account for a very large portion of the total number of compact cars sold. This would tend to support the contention that economy rather than performance is a dominant sales factor.

[1] Displacement: Total volume displaced or "swept" by a single stroke of all pistons; calculated from the engine's bore, stroke and number of pistons.

General Features

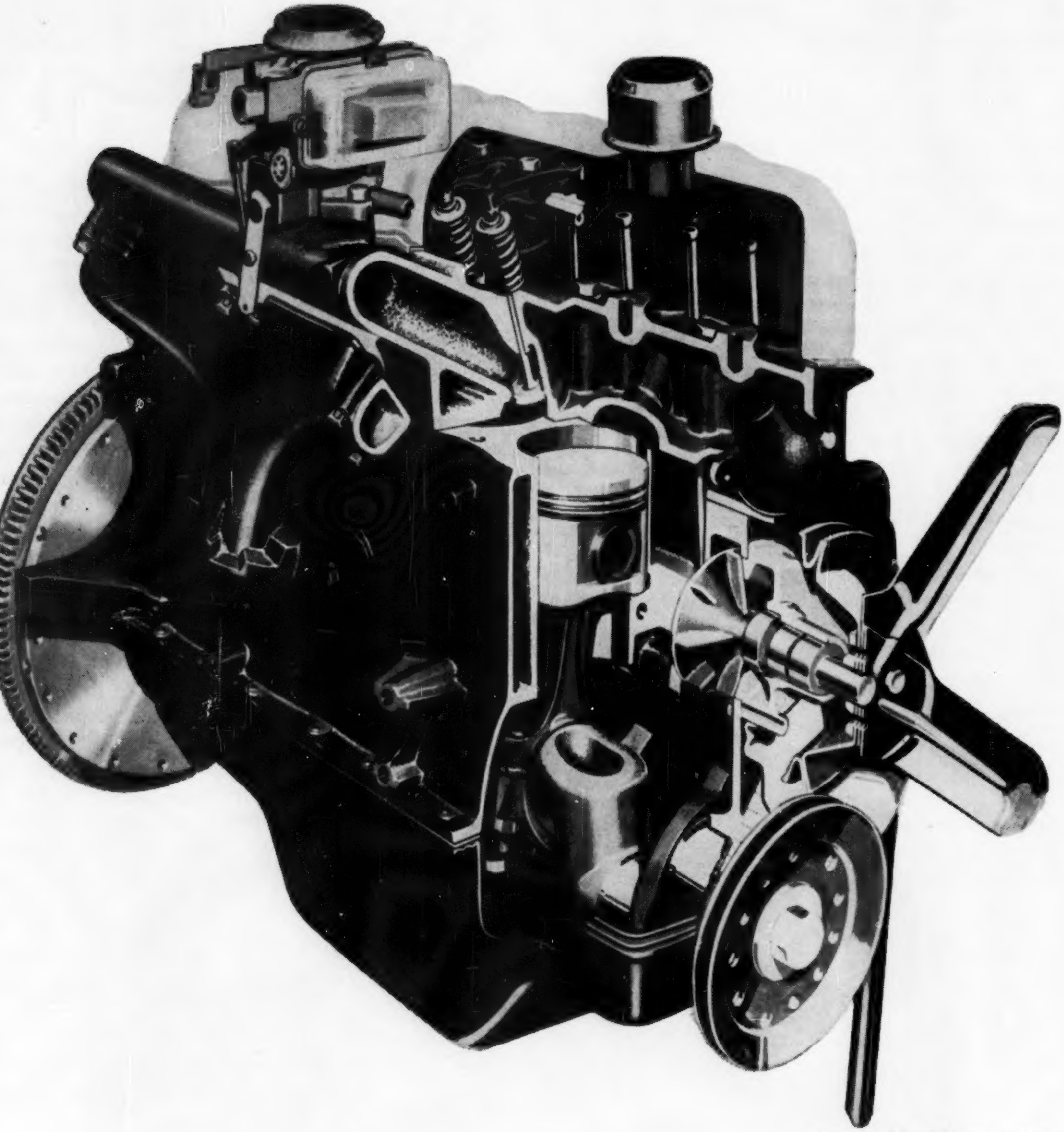
Before discussing specific design features it might be well to mention some of the unusual general features which are found in the present compact car engines. The first of these is the placement or location of the engine. All of the cars except the Chevrolet Corvair have the engine placed in the front of the vehicle. The American-manufactured rear engine car is a novelty on the motoring scene and as such has received considerable attention. However, it should be borne in mind that most of the features embodied in this design have been in use in Europe for many years and while the specific application of production techniques and short-cuts to this arrangement are strictly American, the over-all concept is not new. A similar comment could be advanced regarding the use of air as a cooling medium for this engine although air-cooling was used in the Franklin as late as 1932 and the first Crosley in 1941. A general view of the Corvair engine is shown in Figure 1.

Another factor which is of general interest is the arrangement or placement of the engine cylinders.



Courtesy of Chevrolet Motor Div., GMC

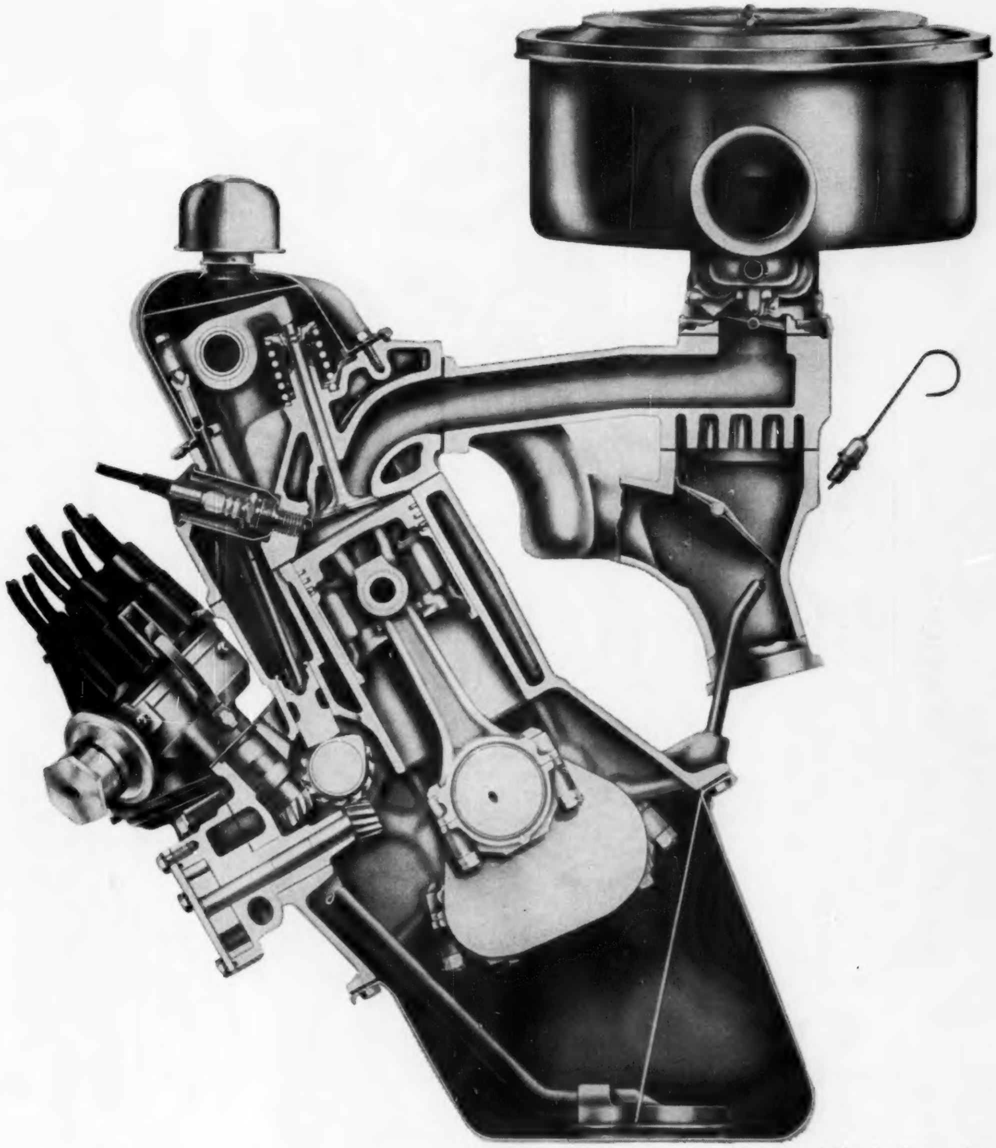
Figure 1 — Chevrolet Corvair engine showing arrangement of component parts.



Courtesy of Ford Motor Company

Figure 2 — Ford Falcon six cylinder in-line engine.

All of the compacts except the Corvair use either the conventional six cylinder in-line arrangement or an eight cylinder engine where the cylinders are arranged to form a "V" with four cylinders on each side of the "V". Both of these designs have been used for over 30 years and have withstood the test of time. A typical six cylinder in-line engine is shown in Figure 2. The Corvair as shown in Figure 1 also uses six cylinders but arranges them in a "pancake" or "flat" form with three cylinders on each side of the engine. This design is commonly referred to as a horizontally opposed design. The advantages of this design are that it readily permits the use of air as a cooling medium. It also permits the complete balance of the engine without the use of counter-weights, since all of the reciprocating forces are cancelled and this results in smoother operation of the engine. This type of design while permitting the maximum utilization of the engine space, is rather wide. It is not suited for mounting between the front wheels, since considerable space must be allowed for front wheel steering. For this reason the horizontally opposed engine has only been successfully used in rear engined cars. It is of interest to note that while this is the first American commercial venture in which this type of engine



Courtesy of Chrysler Corporation

Figure 3 — Chrysler Valiant engine showing 30° "tilt" to drivers right and long intake manifold pipes.

has been used, several other manufacturers have investigated the possibility of using the horizontally opposed design and at least one constructed a prototype although never actually produced the engine in quantity.

Before leaving this general discussion of the design features of the compact car engines, a comment is in order regarding the somewhat novel approach to the front engine mounting problem which has been taken by Chrysler in their Valiant. As shown in Figure 3, the engine is inclined to the driver's right at an angle of 30°. Again, while this approach is not new in foreign cars or American racing cars, it is somewhat novel in those passenger cars produced in America. There are several advantages to this treatment of the engine problem. One of these is the fact that the hood line can be lowered, thus permitting a better view of the road than would be possible were the engine mounted in an upright position. The second is that the center of gravity of the car can be lowered slightly which tends to reduce the body roll or "lean" that might develop when cornering. Other advantages such as more space for the intake manifolding, etc. will be

TABLE II
ENGINE SPECIFICATIONS

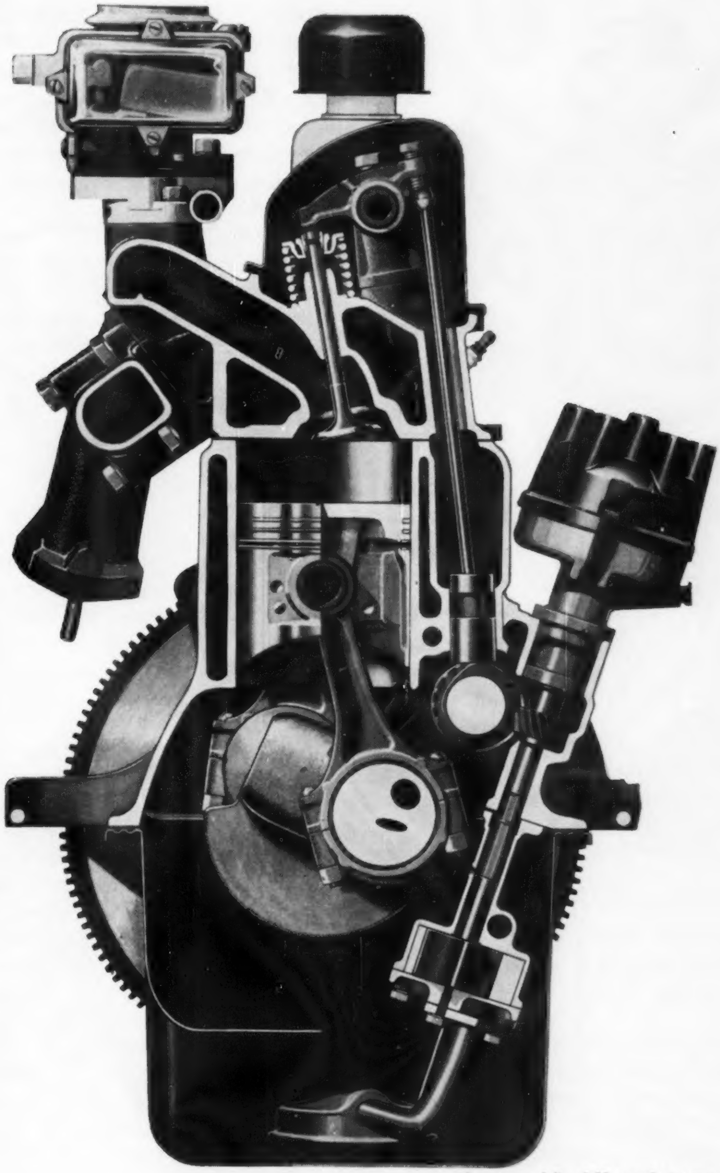
Manufacturer and Make	Location and Cooling	No. of Cyls. and Arrangement	Valve Gear Type	Bore and Stroke (Inches)	Displacement (Cubic Inches)	Compression Ratio	Maximum Horse Power at RPM	Maximum Torque (Ft Lbs) at RPM	HP/Cubic Inch
American Motors Corp.									
Rambler-6	F-W	6-IL	OHV-P	3.125 x 4.25	195.6	8.7:1	127 at 4200[a]	180 at 1600[a]	0.649[a]
Rambler Rebel V-8	F-W	8-V	OHV-P	3.50 x 3.25	250.0	8.7:1	200 at 4900[b]	245 at 2500[b]	0.800[b]
Rambler American	F-W	6-IL	L	3.125 x 4.25	195.6	8.0:1	90 at 3800	150 at 1600	0.461
Chevrolet Motor Div, GMC									
Corvair	R-A	6-HO	OHV-P[c]	3.375 x 2.60	140.0	8.0:1	80 at 4400	125 at 2400	0.572
Chrysler Corp.									
Valiant	F-W	6-IL[d]	OHV-P	3.40 x 3.125	170.0	8.5:1[f]	101 at 4400[f]	155 at 2400[f]	0.595[f]
Ford Motor Company									
Comet	F-W	6-IL	OHV-P	3.50 x 2.50	144.3	8.7:1	90 at 4200	138 at 2000	0.623
Falcon	F-W	6-IL	OHV-P	3.50 x 2.50	144.3	8.7:1	90 at 4200	138 at 2000	0.623
Studebaker-Packard Corp.									
Lark VI	F-W	6-IL	L	3.00 x 4.00	169.6	8.3:1	90 at 4000	145 at 2000	0.531
Lark VIII	F-W	8-V	OHV-P	3.562 x 3.25	259.2	8.8:1	180 at 4500[e]	260 at 2800[e]	0.695[e]

Abbreviations

F = Front
R = Rear
W = Water Cooling
A = Air Cooling
IL = In-Line
V = 90° Vee
HO = Horizontally Opposed
OHV = Overhead Valve System
P = Pushrod Operated
L = "L" Head or Side Valve System

Notes

[a] With optional Twin Throat Carb — 138 BHP at 4500 RPM, 185 ft lbs at 1800 RPM, 0.704 HP/cu in.
[b] With optional Four Bbl Carb and dual exhaust — 215 BHP at 4900 RPM, 260 ft lbs at 2500 RPM, 0.860 HP/cu in.
[c] Hydraulic Valve Lifters, Std Equipment.
[d] Inclined 30° to R.H. Side of Car.
[e] With optional Four Bbl Carb and dual exhaust — 195 BHP at 4500 RPM, 265 ft lbs at 3000 RPM, 0.752 HP/cu in.
[f] With optional "Hyper Pack" of 10.5:1 Compression Ratio and Four Bbl Carb, 148 HP at 5200, 153 ft lbs at 4200, 0.873 HP/cu in.



Courtesy of Ford Motor Company

Figure 4 — Ford Falcon engine showing pushrod-operated overhead valves.

discussed under carburetion and fuel systems.

The lubrication requirements of these somewhat unusual designs are not markedly different from those of the more conventional arrangements and will be discussed later in the section dealing with Engine Lubrication.

A further feature of general interest is the fact that all of the engines used in these compact cars, except the Chevrolet Corvair, use cast iron cylinder *blocks*. While this material is heavier than aluminum, the advantages of using aluminum in small engines is somewhat debatable, especially since the advent of special casting techniques. These newer techniques as applied to the manufacture of cast iron engines greatly reduce bothersome "core shift" and permit the use of minimum wall sections thus eliminating unnecessary weight. Using these techniques the difference in weight between a typical compact car engine block constructed of cast iron and one made of aluminum is only 25 pounds.

It is perhaps for this reason that only one of the compact cars, namely the Chevrolet Corvair, uses

Courtesy of American Motors Corp.

Figure 5 — American Motors Rambler Rebel V-8 engine show-pushrod-operated overhead valves and full flow oil filter at right of crankcase.

aluminum to any great degree as an engine construction material. This was dictated by the need to reduce engine weight to a minimum and by the better cooling characteristics of aluminum. In this engine both the cylinder head and crankcase are made from this material although the cylinders are made from cast iron. It is interesting to note that the low pressure permanent mold aluminum casting process used to manufacure this engine was developed in England during World War II by Lewis, Tinsley and Peters.

From the foregoing it should not be inferred that aluminum can only be used in the Corvair design where *air* is used as a coolant. Other manufacturers are making rapid strides in the development of larger aluminum *water* cooled engines where the weight advantage is more pronounced. A few are planning the introduction of these engines at an early date.

Compression Ratio

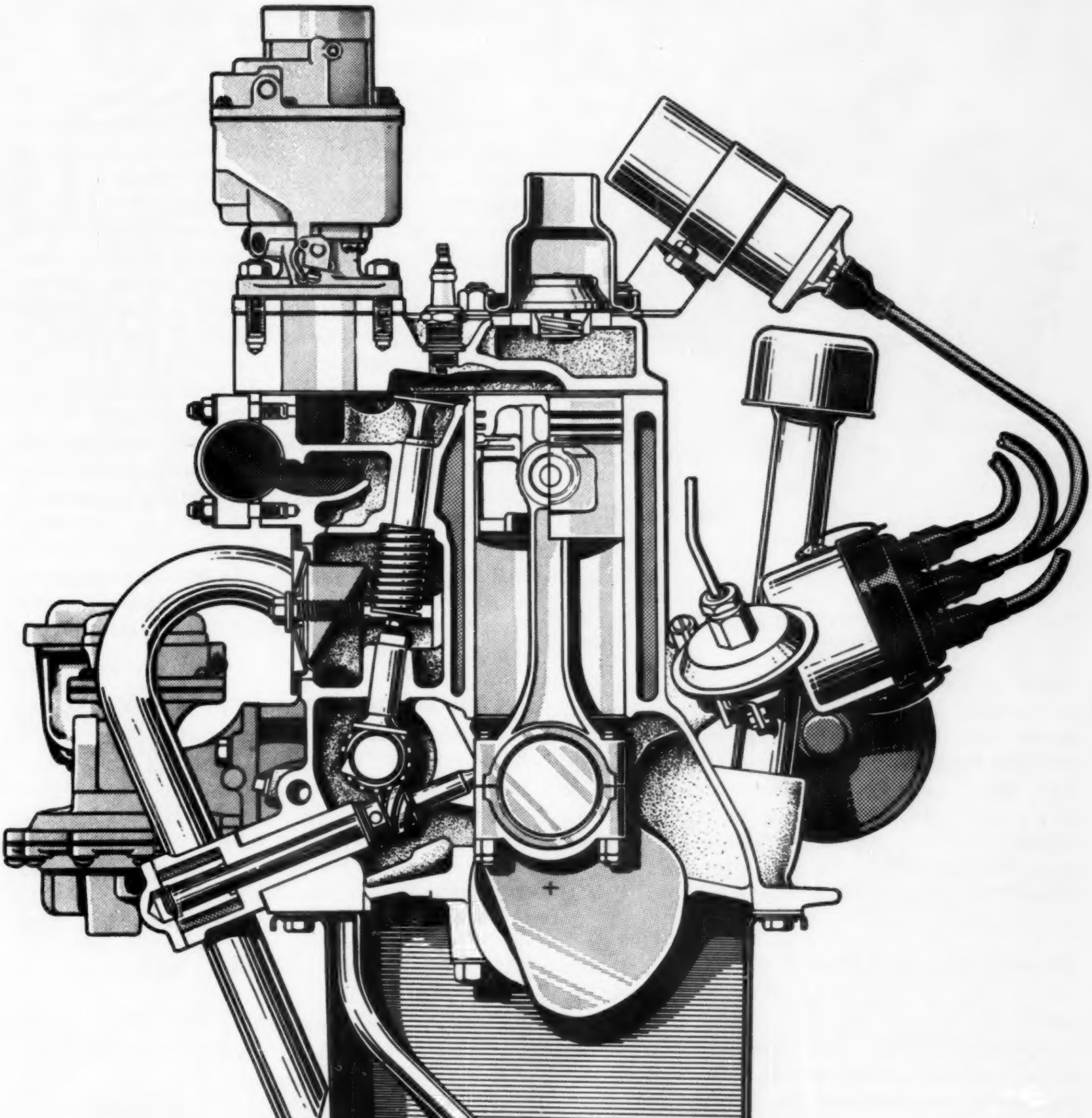
The modern spark ignition internal combustion engine consists of many individual parts which perform many different functions. All of the engines used in American cars are of four cycle design wherein the charge of vaporized fuel and air is inducted into the cylinder during the intake stroke or cycle; is compressed during the compression cycle; is ignited and burned during the power cycle and the burned gases are exhausted during the exhaust cycle. Since one complete power stroke requires four different cycles or piston strokes, an engine using this system is called a four cycle or four stroke cycle engine.

In all internal combustion engines the total amount of power available as useful work at the engine output shaft is determined by the amount of fuel that can be burned per power cycle, the amount of work that can be extracted from this burning fuel minus thermal losses and the losses due to gas and mechanical friction. The amount of fuel that can be burned depends on the *weight* of correct fuel-air mixture that can be gotten into the cylinder on the intake stroke. This depends on many factors such as the engine manifolding, valves, carburetor and camshaft design, etc. The amount of work developed from the burning gases depends primarily on the expansion ratio or in more common terms, the compression ratio. It is this factor that has the greatest effect on engine gasoline economy. It will be noted in Table II that all of the compact cars are supplied with compression ratios approximating 8.4 to 1, although higher compression ratios are optionally available in the Valiant. Compression ratios in the range of 8.0 to 8.8 to 1 generally permit knock-free operation on today's regular-grade gasoline.

Valve Systems

While racing cars and many of the high performance European cars use the overhead camshaft arrangement acting directly on the valves, American automotive practice has been to use either the pushrod-operated overhead valve system or the side valve or L-head system. This also applies to the present compact cars. All except two use the pushrod operated overhead valve system, similar to that shown in Figure 4. While it may be argued that the advantages of this type of system do not warrant the extra cost and complexity necessary to its operation, it does permit the use of higher compression ratios than are possible with the side valve system. In addition it reduces the internal gas flow losses which occur during the intake and exhaust stroke and thus tends to increase engine power, particularly at high engine speeds. While the use of this type of valve system does allow these improvements in operation, it also results in some extra complication of the valve system which some designers feel is not economically justified. Similarly the larger V-8 engines available in both the Lark VIII and Rambler Rebel are also equipped with pushrod operated overhead valves, the latter being shown in Figure 5.

Neither the six cylinder Rambler American shown in Figure 6 nor the Lark VI use the overhead valve system preferring instead to continue the use of the side valve or "L" head engine. This results in a simple, relatively uncomplicated short valve train

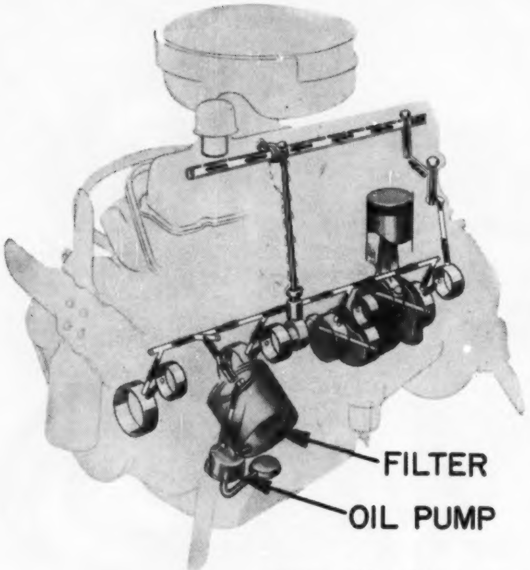


Courtesy of American Motors Corp.

Figure 6 — American Motors Rambler American engine showing "L" head with valves in engine block.

which is not subject to the larger variations in valve lash which normally occurs with the overhead arrangement. Offsetting this advantage is the greater difficulty of valve adjustment when it is necessary.

It is interesting to note that of *all* of the engines used in compact cars, only the Chevrolet Corvair has used hydraulic valve lifters. This was probably dictated by the fact that in general, an air cooled engine will run somewhat hotter than a water cooled engine, thus resulting in a greater variation in valve clearance from cold to hot. To eliminate this difficulty and possible source of customer annoyance,



Courtesy of Ford Motor Company

Figure 7 — Typical engine lubricating system showing full flow oil filter.

hydraulic valve lifters are used. This engine is also unusual in that the camshaft is somewhat different from the conventional design where each intake and exhaust valve is operated by its own cam lobe. The Corvair engine employs a camshaft with only three extra wide exhaust lobes so that two exhaust valves of opposing cylinders are operated by each lobe. While no particular advantage is claimed for this design it is interesting in that it is unusual and novel.

Displacement and Bore-Stroke Ratio

Referring to Table II it will be immediately apparent that in general, all of these engines are considerably smaller than those used in the so-called full scale American car. Their piston displacements, not including the V-8 engines, range from 140 to 196 cubic inches as compared to an average of 326 for all 1960 American car engines. The larger engines are those used by Rambler and Lark whereas the smaller engines are used in the newer cars such as the Comet and Valiant. Generally an "oversquare" design, where the bore is greater than the stroke, permits higher engine operating speeds. The longer stroke engines, while operating at somewhat lower speeds, tend to develop more engine torque which is an advantage in accelerating in the low speed range.

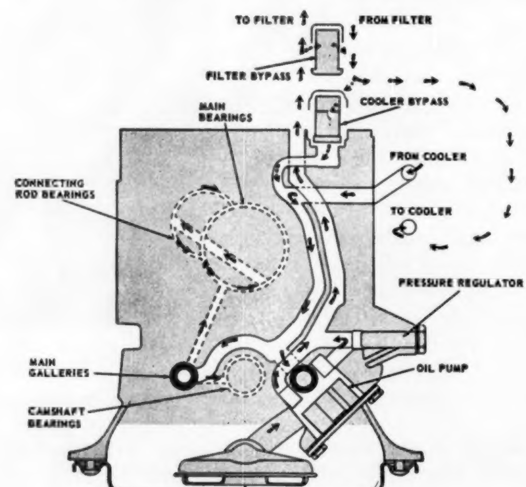
Other engine operating characteristics such as top engine speed, internal friction, intake manifold gas dynamics and cooling requirements all affected the selection of the bore and stroke ultimately decided upon. These items will not be discussed since they are outside the scope of this article.

Horsepower Per Cubic Inch

Paralleled with the foregoing discussion of the bore-stroke ratio and the effect of stroke on engine operating speed is the consideration of the over-all design from the standpoint of the efficiency of displacement utilization. Traditionally, this factor is measured by dividing the maximum horsepower developed from the engine in question by the displacement of this engine. The factor, horsepower per cubic inch is thus determined and is shown in Table II. To orient the reader, values of from 0.500 to 0.600 are common on foreign cars exclusive of the sports and racing models. In these automobiles factors of 1.00 or over are common. Another way of looking at this figure is to consider it as a measure of the amount of stress an engine is subjected to when called upon to develop maximum horsepower. It will be noted by referring to Table II that all of the engines have values below 0.80 which indicates that in general they are lightly stressed engines and should give good durability. The average of all 1960 American made cars is 0.729 and the maximum is 0.885.

Engine Lubrication and Lubrication Systems

All the current compacts employ full pressure lubrication as indicated in Table III. Some have special oil jets in the connecting rods to cool the under side of the pistons and provide supplemental cylinder wall lubrication. A typical lubrication system is shown in Figure 7. All of the engines use or have optionally available oil filters of either the full flow type or partial flow type. A full flow filter



Courtesy of Chevrolet Motor Div., GMC

Figure 8 — Chevrolet Corvair engine lubrication system showing oil flow to filter and cooler.

TABLE III
CAR MANUFACTURERS ENGINE LUBRICANT RECOMMENDATIONS

Manufacturer and Make	Oil System Type	Oil Filter Type	Crank-case Refill Capacity Qts.[a]	Oil Type	SAE Viscosity Grade when Expected Ambient Temperature is: Above +32°F	Between +32°F and +10°F	Between +10°F and −10°F	Below −10°F
American Motors Corp								
Rambler 6	Pr	Pa-O	4.0	MM or MS	20[b]	20W[b]	10W[b]	5W[c]
Rambler Rebel V-8	Pr	FF-O	4.0	MM or MS	20[b]	20W[b]	10W[b]	5W[c]
Rambler American	Pr	Pa-O	4.0	MM or MS	20[b]	20W[b]	10W[b]	5W[c]
Chevrolet Motor Div, GMC								
Corvair	Pr[d]	FF-S	4.0	MS or DG	30[e]	10W	10W	5W-20
Chrysler Corporation								
Valiant	Pr	FF-S	4.0	MS	30[bf]	20W[bf]	10W[be]	5W[c]
Ford Motor Company								
Comet	Pr	FF-S	3.5	MS	20W	10W	10W	5W
Falcon	Pr	FF-S	3.5	MS	20W	10W	10W	5W
Studebaker-Packard Corp.								
Lark VI	Pr	Pa-O	5.0	MS or DG	30[bf]	20W[b]	10W[b]	5W[c]
Lark VIII	Pr	Pa-O	5.0	MS or DG	30[bf]	20W[b]	10W[b]	5W[c]

Abbreviations:

Pr = Pressure Lubrication System
Pa = Partial Flow
O = Optional
S = Standard
FF = Full Flow
MM = API Service Classification MM
MS = API Service Classification MS
DG = API Service Classification DG

Notes:

[a]Does not include oil filter.
[b]SAE 10W-30 may be used.
[c]SAE 5W-20 may be used.
[d]Fitted with oil cooler as standard.
[e]If daytime temp above 10°F, always use SAE-30.
[f]SAE 20W-40 may also be used.

is shown in the lubrication system shown in Figure 5. In general, water cooled engines permit engine operation without the need of oil coolers. However, when air is used as a cooling medium, engine and oil temperatures are sufficiently high so that an oil cooler is often necessary. This is the case with the Chevrolet Corvair. Figure 8 shows the oil system of this engine and indicates that all of the engine oil is first passed through both the oil filter and oil cooler before being delivered to the engine parts.

Table III also indicates the recommended engine lubricants of the various compact cars. It will be noted that the lubricants are identified by both the SAE Viscosity Grade and by Type. The Viscosity Grade refers to the SAE viscosity classification system which is in common usage throughout the United States. This classification system is shown in Table IV.

In Table III, oils are identified as "MM," "MS" or "DG." These designations refer to the API (American Petroleum Institute) Service Designation System of oils which is based upon the various service conditions which may be encountered by both gasoline and diesel engines and which affect the type of oil required. For example the designation MM refers to API Classification "Motor Medium" and defines an oil which the refiner feels is suitable for use in gasoline "Motors" operating

TABLE IV
SAE Viscosity Grade Classification, Motor Oils

SAE Viscosity Grade Number	Viscosity (Saybolt Universal Seconds) at 0°F. Minimum	at 0°F. Maximum	at 210°F. Minimum	at 210°F. Maximum
5W		4,000		
10W	6,000	12,000	39	
or		12,000	40	
20W	12,000	48,000		
or		48,000	45	
20			45	58
30			58	70
40			70	85
50			85	110

under "Medium" service conditions. Similarly the designation MS refers to an oil which the refiner feels will be suitable when used in "Motors" operating under "Severe" conditions. Unfortunately the driving public does not usually understand and is frequently mislead by these terms. For example the type of service which many people feel is "Light" such as driving to the station or around town where no high speed operation is involved, is actually a most "Severe" type. Two thirds of today's trips are of less than eight miles. Under such conditions engine and especially oil temperatures are low, thus tending to promote incomplete combustion of the fuel charge. This results in partially burned gasoline being forced by the piston rings and into the crankcase. This together with the other products of combustion such as carbon and water vapor, contaminate the engine oil and cause crankcase sludging, oil screen clogging, fuel varnish and hydraulic valve lifter sticking, rust, corrosion, piston and other *low* temperature deposits. This situation is aggravated by prolonged engine idling especially in cold weather. Unless protected by a heavy duty oil (MS, DG or higher) an engine subjected to this "light" duty will also wear out at least twelve times faster than if it were operated steadily on long trips at moderately high crankcase and jacket temperature. Practically all engine manufacturers now recommend an oil of at least MS Service Designation for stop-and-go driving; to remove the contaminants, crankcase drains as low as 500 miles or every month are required.

At the other extreme, high temperature and high speed operation are also included under this MS designation since they tend to promote oil oxidation which may cause *high* temperature engine deposits. Severe operation in hot weather tends to aggravate these conditions.

Service MM is a more moderate type of classification defining gasoline engine service where only relatively high speeds or heavy loads may be encountered. It does not include extensive operation under the low speed stop-and-go type of driving described above under Service MS.

Service DG classifies that type of service which may be encountered in *diesel* engines under "Good" operating conditions. An oil assigned this service designation would, in the refiner's opinion, be satisfactory for use in diesel engines where wear and deposit control were not a problem. By reason of their heavier fuel and their higher peak combustion pressures, diesel engines tend to promote more rapid oil oxidation and contamination than would normally be experienced in a gasoline engine. Because of this, a more highly detergent oil is necessary for use in diesel engines. Diesel engine lubricants give very satisfactory service when used in gasoline engines and are able to give a greater degree of protection against oil oxidation, corrosion and wear than would normally be expected from an oil designed only for use in gasoline engines.

Oil Change Intervals

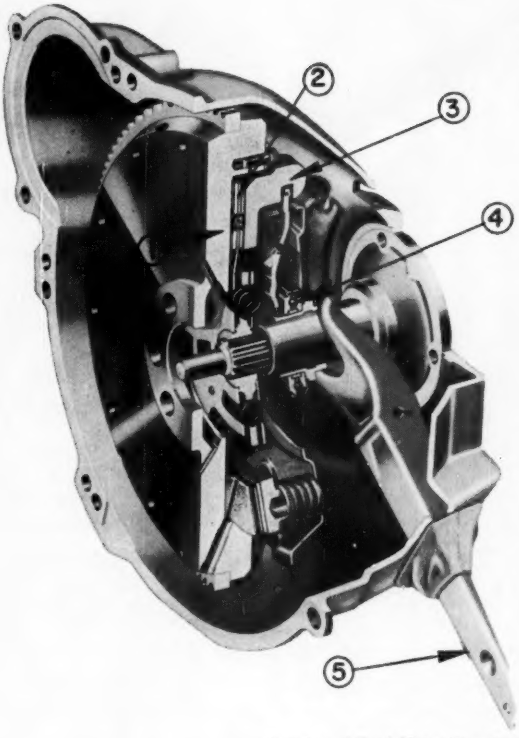
A discussion of oil change intervals usually results in controversy since the discussions are usually based on such different criteria as air temperature, mileage, road conditions, engine type and operating conditions. In any case the main reason for changing oil is to assure that contaminants are removed from the engine before they can damage it. For much the same reason draining is also necessary to assure that the oil is replaced *before* the effectiveness of its dispersants, anti-oxidants, corrosion inhibitors and other additive agents is diminished below minimum safe limits. There is no hard and fast rule since the status of each or all of these conditions depends on the type and time of service as well as the original quality of the oil. Also to be considered is the amount of make-up oil which has been added since the last complete engine oil drain. A final factor and one that is often overlooked is whether the oil system is fitted with an oil filter, whether the filter is of the full or partial flow type and the time since the filter element was last replaced. In their Owners Manuals automotive manufacturers recommend oil change intervals in terms of the type of service. For example under dusty conditions the oil should be drained more often than under highway driving conditions. Similarly, winter operation involving considerable short trips of the stop-and-go type would indicate that more frequent oil changes should be made; every 500 to 1000 miles. Under long trip conditions in temperate climates where extreme high temperatures are not encountered, oil drain intervals of 2000 miles have been recommended. In general, as the severity of operating conditions increases, more frequent drains are required.

As a result of continuing study of the many factors in this complex matter, the Lubrication Committee of the API Division of Marketing recently recommended the following simplified oil drain recommendations:

"In winter............... every 30 days
In summer.............. every 60 days
But never to exceed 2000 miles"

Fuel Systems and Manifolding

Before leaving the discussion of the compact car engine it might be well to consider briefly the fuel system, with special emphasis on intake manifold designs. With the exception of the V-8 engines, the Lark VI and Valiant, all engines have intake manifolds cast into cylinder head or block as shown in Figures 1, 2, 4 and 6. This arrangement has several advantages in that it improves the warm-up characteristics of the engine and also results in more com-



Courtesy of Ford Motor Company

Figure 9 — Typical single-disc clutch showing main operating parts: (1) engine flywheel, (2) clutch disc, (3) pressure plate, (4) throw-out bearing, (5) clutch release lever.

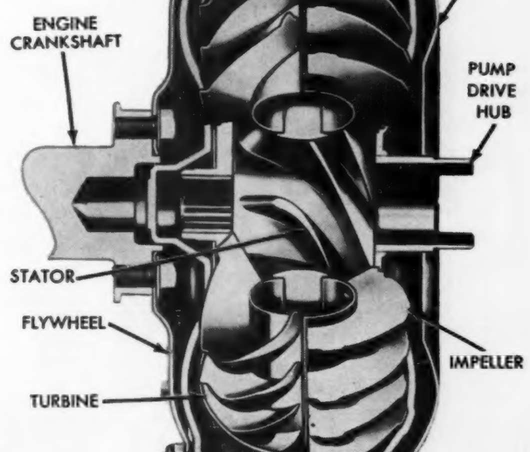
plete vaporization of the fuel. Both of these factors tend to improve fuel economy. The Valiant, as shown in Figure 3, due to the inclination of the engine, is able to use a rather novel type of design wherein each cylinder is served with a separate long manifold passage. This tends to improve the fuel distribution thus promoting smoother engine operation. This arrangement has the additional advantage that the dynamic effects of the air moving down the relatively long intake manifold induces a supercharging effect at certain engine speeds which results in somewhat more power than would be obtainable with a more conventional manifolding system.

CLUTCHES

In order that the engine may be coupled with the transmission and the rest of the drive train, the engine power must be transferred through some sort of disconnecting device. This is necessary in order to be able to start or stop the car and still keep the engine running and to permit gear changing. This is accomplished by means of a clutch similar to that shown in Figure 9. Typically the clutch consists of a disc faced with an appropriate friction material, which is clamped between a "pressure plate" and the engine flywheel. Both the pressure plate and the engine flywheel rotate at all times with the engine. The clutch disc is attached to the transmission input shaft and when clamped between the pressure plate and the flywheel, or "engaged", drives the transmission input shaft. Depressing the clutch pedal draws the pressure plate away from the flywheel thus releasing the clutch driven disc so that a different transmission gear may be engaged or the car may be stopped without stalling the engine.

Generally, all of the clutches used on compact cars are similar and make use of no unusual or novel design features. They do not require lubrication since the clutch throw-out bearing is packed with a suitable grease at the factory and then sealed for life. The grease selected for this difficult condition must have good oxidation resistance and be resistant to excessive working down lest it liquefy and run out of the bearings onto the friction clutch facing.

In those cars equipped with automatic transmissions, coupling between the engine and transmission is usually effected by means of a "torque converter" (combination fluid coupling and torque converter). These units use an impeller, attached to the engine, to create a rotation of the oil within the housing which in turn causes the rotation of a second set of blades, called the turbine, attached to the transmission input shaft. There is no direct mechanical connection between the engine and the transmission as in a conventional clutch. While it is not intended to



Courtesy of Ford Motor Company

Figure 10 — Typical torque converter showing main operating parts.

TABLE V
TRANSMISSION AND DIFFERENTIAL SPECIFICATIONS

	Transmission					Converter	Overdrive		Differential				
			Gear Ratios in Speeds								Gear Ratios		
Manufacturer and Make	Type	Shift Location and No. of Speeds	1st	2nd	3rd	Stall Ratio	Type	Ratio	Design Type	Gear Type	Standard	Standard with Overdrive	Optional
American Motors Corp.													
Rambler 6	M	C-3	2.61	1.63 Sy	1.0 Sy	...	BW	0.70:1	TT	HP-LSO	3.78	4.11	4.38
	A	C-3	2.40	1.47	1.0	2.12	..	...	TT	HP-LSO	3.31	...	3.78
Rambler Rebel V-8	M	C-3	2.57	1.55 Sy	1.0 Sy	...	BW	0.70:1	TT	HP-LSO	4.10	4.10	4.44
	A	C-3	2.40	1.47	1.0	2.12	..	...	TT	HP-LSO	3.15	...	3.55
Rambler American	M	C-3	2.61	1.63 Sy	1.0 Sy	...	BW	0.70:1	Ho	HP-LSO	3.31	3.78	4.11
	A	C-3	2.40	1.47	1.0	2.12	..	...	Ho	HP-LSO	3.31	...	...
Chevrolet Motor Div.,													
GMC	M	F-3	3.22	1.84 Sy	1.0 Sy	...	NA	...	TR	HP	3.55	...	3.89
Corvair	A	D-2	1.82	1.0	...	2.60	..	...	TR	HP	3.55	...	3.89
Chrysler Corporation													
Valiant	M	F-3	2.71[a]	1.83 Sy[a]	1.0 Sy[a]	...	NA	...	Ho	HP	3.55	...	3.23, 3.90
	A	D-3	2.45[a]	1.45[a]	1.0[a]	2.25	..	...	Ho	HP	3.55	...	3.23
Ford Motor Company													
Comet	M	C-3	3.29	1.75 Sy	1.0 Sy	...	NA	...	Ho	HP	3.10	...	3.56
	A	C-2	1.75	1.0	...	2.40	..	...	Ho	HP	3.56	...	...
Falcon	M	C-3	3.29	1.75 Sy	1.0 Sy	...	NA	...	Ho	HP	3.10	...	3.56
	A	C-2	1.75	1.0	...	2.40	..	...	Ho	HP	3.10	...	3.56
Studebaker-PackardCorp.													
Lark VI	M	C-3	2.61	1.63 Sy	1.0 Sy	...	BW	0.70:1	Ho	HP-LSO	3.73	4.1	4.27
	A	C-3	2.40	1.47	1.0	2.15	..	...	Ho	HP-LSO	3.73	...	4.1
Lark VIII	M	C-3	2.57	1.55 Sy	1.0 Sy	...	BW	0.70:1	Ho	HP-LSO	3.31	3.54	...
	A	C-3	2.40	1.47	1.0	2.15	..	...	Ho	HP-LSO	3.07	...	...

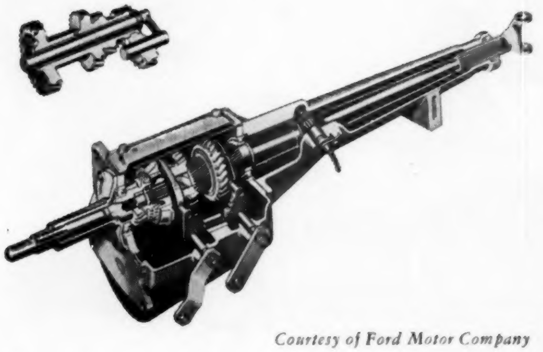
Abbreviations

M = Manual
A = Automatic
C = Steering Column
D = Dash Mounted
F = Floor Mounted
Sy = Synchronized
BW = Borg-Warner (Planetary)

TT = Torque Tube
Ho = Hotchkiss Drive
TR = Transaxle
HP = Hypoid
LSO = Limited Slip Available As Option
NA = Not Available

Note

[a]With "Hyper Pack" 2.31, 1.55 Sy and 1.0 Sy Optionally available.



Courtesy of Ford Motor Company

Figure 11 — Typical three speed manual transmission showing countershaft drive gears, synchronizers and shifting mechanism.

discuss their hydraulic principles,[2] it can be said that the torque converter incorporates a set of blades known as a "stator" which tends to multiply the engine torque by redirecting the circulatory fluid motions set up by the impeller. A typical torque converter is shown in Figure 10.

TRANSMISSIONS

Before discussing the various features of the manual and automatic transmission that are available in the compact car, it might be well to first consider the function of the transmission in the operation of the car. Basically, a transmission is a device wherein the engine speed is modified through various gear ratios so as to permit the car to be operated over a wide speed range with an engine whose usable speed range is limited. The proper selection of gear ratios in a particular car is important. They must be matched to the performance characteristics of the engine and the acceleration performance desired. Their selection is also based on other considerations such as the vehicle weight and the rear axle ratios available as standard or optional equipment. Generally, the less flexible the engine operating range or the less power the engine can develop, the more speeds are required in the transmission to assure acceptable car performance. The specifications of these transmissions are shown in Table V.

Manual Transmissions

All of the compact cars offer a manual transmission as standard equipment. Unlike foreign cars, where the four speed transmission is almost standard, the performance characteristics of the American compact car engines are such that three speed transmissions are considered adequate. Their design is generally conventional and in line with usual transmission practice in that they are all of the constant mesh type and have the second and third speed ratios equipped with synchronizers. This can be seen in Figure 11 which shows a partial cutaway of a typical transmission. The countershaft drive gear and reverse idler gear are more clearly shown at the upper left of Figure 11.

As indicated previously, synchronizers are used in the second and third speeds of all the transmissions. This is necessary in order that the gear changes may be accomplished easily and quickly without "clashing" as used to be the case in transmissions of thirty or more years ago. The synchronizer is a relatively simple device and typical design is shown in Figure 12. When a different speed is to be engaged, the movement of the shifting lever first engages a small brass or bronze cone clutch with the selected gear in order that their relative speeds can be equalized or *synchronized*. When the two speeds are equal, final engagement of a "dog" type clutch occurs which allows the transmission of power. Since all of this occurs within a very short interval of time, the two individual actions are not readily separated.

While those transmissions used in most of the compact cars are relatively conventional, the Corvair design is somewhat novel in that the power is transmitted to the transmission through a shaft which

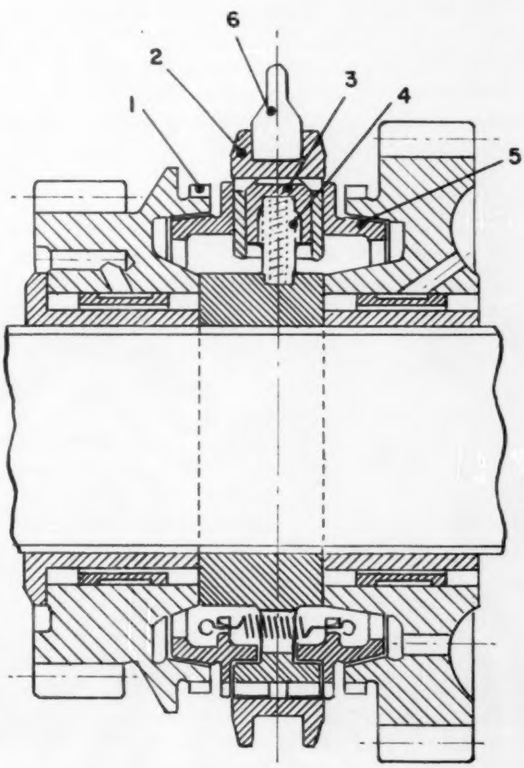
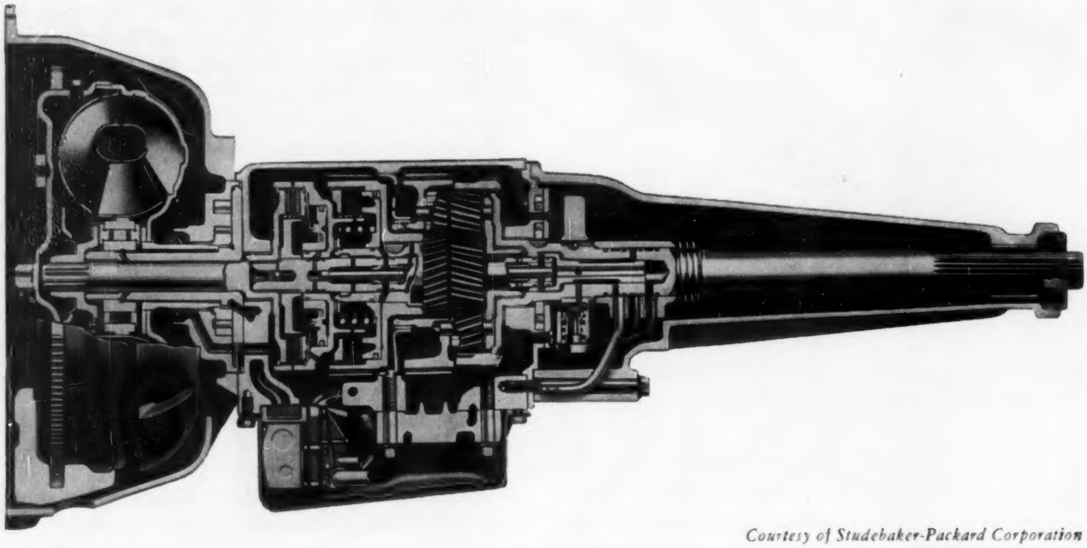


Figure 12 — Schematic view of "constant load" type of synchronizer.

[2] For more complete discussion see Lubrication, November 1954, "Evolution of the Chrysler PowerFlite Automatic Transmission."



Courtesy of Studebaker-Packard Corporation

Figure 13 — Lark Flightomatic automatic transmission showing planetary gearing, clutches and bands used to affect speed changes.

operates "inside" of the output shaft. This design will be discussed in greater detail in the section dealing with Transaxles.

The lubrication requirements for the various manual transmissions used in these cars are not unusual in that they do not deviate markedly from normal automotive lubrication practice. They will be discussed further in the forthcoming section dealing with Transmission Lubrication.

Automatic Transmissions

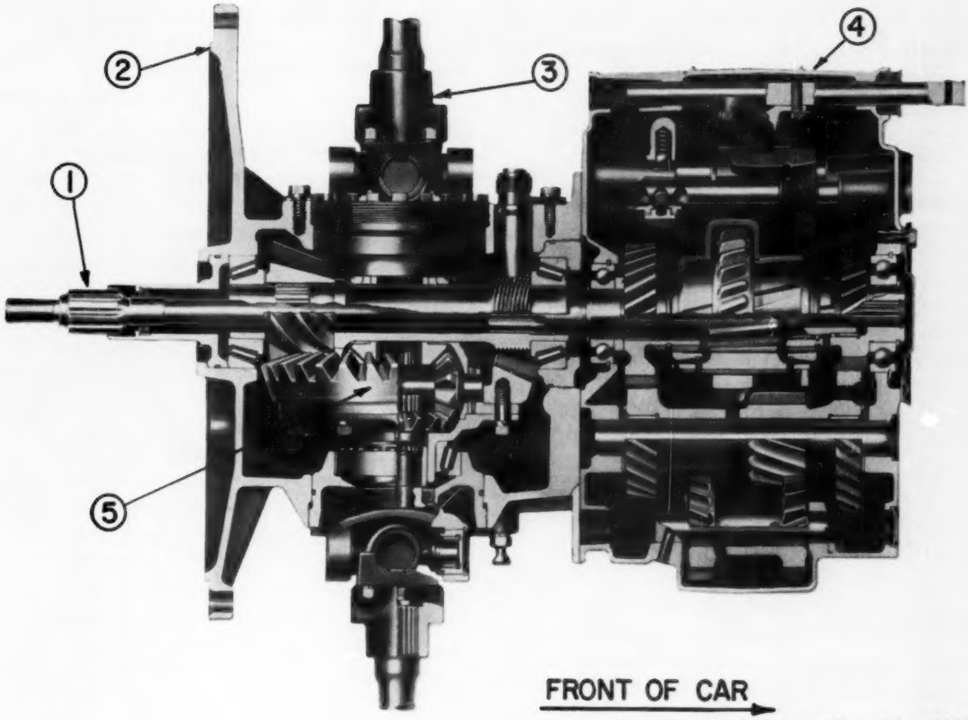
As indicated previously all of the compacts have available as optional equipment, an automatic transmission. While they all differ slightly in detail and in the number of speeds provided, they all operate on the same general principle. All transmissions use planetary gearing to effect the necessary speed reduction in the intermediate gears. All are equipped with hydraulically operated clutches or bands which permit the automatic shifting of gears; and finally, all are preceded by torque converters. A typical automatic transmission as found in the compact cars is that shown in Figure 13. The lubrication requirements of these automatic transmissions will be discussed in a following section.

Transaxle
(Combined Transmission-Differential)

In this design the transmission and the differential are mounted together so as to form one integral unit. Manual transmissions of this type have been used both here and abroad for many years. The Volkswagen, Porsche, Renault, Citroen and Lancia are a few of the foreign cars utilizing this arrangement. The Cord, which was manufactured briefly during the early and late 1930's, also used this combined transmission-differential arrangement. While the Corvair uses this basic idea, it differs from other designs in certain details. For example and as indicated in Figure 14, the Corvair's engine is bolted to a flange (No. 2) which is to the rear of the rear wheels while the transmission section (No. 4) of the transaxle is to the front with the hypoid differential (No. 5) driving the rear wheels through swing axles (No. 3). The drive from the engine to the transmission is accomplished by running the drive shaft (No. 1) "inside" the transmission output shaft. The power, after having gone through the gears is returned to the differential pinion by a shaft which surrounds the transmission drive shaft. (In previous designs of this general type the drive entered the transmission through one shaft and was then directed to the differential pinion gear through another shaft that was entirely separate from the transmission drive shaft.)

While the combined *manual* transmission and differential unit has been used on other cars, Corvair is the first production automobile to use a combined *automatic* transmission and differential. This transmission is shown in Figure 15 and also utilizes the same general principle of returning the power from the transmission to the differential pinion along a shaft surrounding the transmission input shaft.

The automatic transmission used in the Chevrolet Corvair is a two speed design preceded by a single-stator torque converter. While the principles of operation of this automatic transmission are identical to those used in other cars, this design is rather



Courtesy of Chevrolet Motor Div., GMC

Figure 14 — Chevrolet Corvair combined manual transmission and differential unit (horizontal section).

Courtesy of Chevrolet Motor Div., GMC

Figure 15 — Chevrolet Corvair combined automatic transmission and differential unit (vertical section).

TABLE VI

CAR MANUFACTURERS TRANSMISSION AND DIFFERENTIAL LUBRICANT RECOMMENDATIONS

	Manual Transmission					Automatic Transmission		Differential				
	Refill	Oil	SAE Viscosity Grades For			Refill	Oil	Refill	Oil	SAE Viscosity Grades For		
Manufacturer and Make	Cap. (Pints)	Type	Summer	Winter	Ext. Cold	Cap. (Quarts)	Type	Cap. (Pints)	Type	Summer	Winter	Ext. Cold
American Motors Corp.												
Rambler 6	1.5[a]	MO	40	40	40	10	A	3.0	HP[e]	90	90	80
Rambler 6 American	1.5[a]	MO	40	40	40	10	A	3.0	HP[e]	90	90	80
Rambler Rebel V-8	2.25[b]	MO	40	40	40	10	A	4.0	HP[e]	90	90	80
Chevrolet Motor Div., GMC												
Corvair	2.0	GO	80	80	80	3.0	A-SA	3.0	GL-4	80	80	80
Chrysler Corporation												
Valiant	4.0	GL-4	80	80[c]	80[c]	6.5	A-SA	2.0	GL-4	90[f]	80[f]	75[f]
Ford Motor Company												
Comet	2.5	HP	80	80	80	6.25	A-SA	2.0	HP	90	80[g]	80[g]
Falcon	2.5	HP	80	80	80	6.25	A-SA	2.0	HP	90	80[g]	80[g]
Studebaker-Packard Corp.												
Lark VI	2.8[d]	MO	30	30	30	9.0	A-SA	2.5	GL-4	90	90	90
Lark VIII	2.8[d]	MO	30	30	30	9.0	A-SA	2.5	GL-4	90	90	90

Abbreviations:

A = Automatic Transmission Fluid, Type A
SA = Suffix A
GO = Mineral Gear Oil
GL-4 = Multipurpose Type Gear Lubricant, API Service GL4
HP = Hypoid Gear Lubricant
MO = Motor Oil, API Service MS

Notes:

[a] With Overdrive, capacity is 2.75 pints.
[b] With Overdrive, capacity is 3.5 pints.
[c] Above −10°F. SAE 80, Below −10°F. SAE 75.
[d] With Overdrive, capacity is 4.0 pints.
[e] If equipped with limited slip differential, use special lubricant.
[f] Above −10°F. SAE 90, Below −10°F. SAE 80, Below −30°F. SAE 75.
[g] Above −25°F. SAE 90, Below −25°F. SAE 80.

novel in that the whole unit has been compacted so as to be as light as possible. It will be noted that this design uses three concentric shafts. The innermost of these is connected directly to the engine and used to drive the transmission pump. The intermediate shaft drives the transmission itself and the outermost of these three concentric shafts returns from the transmission and drives the hypoid pinion of the differential. The transmission housing is made of aluminum for lightness.

Overdrive Units

While overdrive units are not available on all compact cars, they are furnished as optional equipment on both the Lark and Rambler. Their function is to reduce the engine speed during high speed cruising below that which would normally occur were the overdrive not available. The use of the overdrive, while reducing the engine speed for the same road speed, also reduces gasoline consumption and to some extent engine wear. The Borg-Warner unit used on these cars consists of a planetary gear set which is engaged by the driver through the temporary release of the accelerator pedal. These units are fitted with a governor which does not permit the engagement of overdrive below a certain preset speed, usually 25-30 MPH. To obtain faster acceleration for passing, and good hill climbing ability, the accelerator is pressed to the floor which causes a momentary interruption of the engine ignition, disengages the overdrive unit, and returns the unit to its straight-through high-gear operation. A mechanically operated "lock-out" can be engaged by the driver as desired to render the unit inoperative.

Lubrication of the overdrive unit can be accomplished either from the transmission supply or from a separate supply within the overdrive itself. In all but the Rambler Rebel V-8, the overdrive has its own supply of lubricant and must be filled separately. In all cases, however, the same viscosity and type of lubricant used in the transmission is also suitable in the overdrive.

Transmission Lubrication

Transmission lubricants can be divided roughly into two general categories; those used in manual transmissions and those used in automatic transmissions. This grouping is necessary since the requirements of the manual transmission make a lubricant suitable for use in this unit unsuitable in an automatic transmission. However, the converse of this is not true, since some European cars do use automatic transmission lubricants in their manual transmissions. One American manufacturer has recently adopted this practice.

Generally, passenger car manual transmissions use a so-called "splash" type of lubrication wherein the gears operate in a bath of oil which is splashed around on other moving parts by their rotation. Thus the oil is thrown to all points within the transmission case to provide the necessary lubrication.

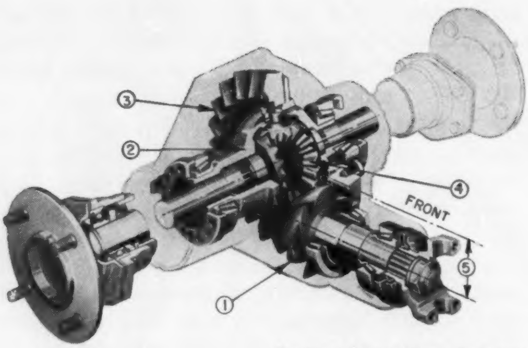
The lubrication requirements of these transmissions are determined by several factors. The most important of these is the temperature range over which the transmission will be expected to operate. If a light viscosity oil is used due to a low temperature requirement, and is still used under high temperature conditions, it may thin out excessively and cause unwanted transmission wear. This could occur since many of the gears, bearings and bushings do have a minimum viscosity requirement below which excessive wear may develop. Conversely, were a lubricant suitable for summer driving used under extreme cold conditions, it would stiffen to the point where it would not flow. Should this occur, the lubricant would "channel" and the gears and bearings would soon run dry thus promoting serious damage.

To assure that oils of equivalent viscosities are universally available, the SAE Transmission and Axle Lubricant Viscosity Classification shown in Table VII was established and is now universally used. It should be kept in mind that the SAE system defines oil *viscosity* only, usually only at one temperature, and does not include other desirable oil qualities such as oxidation resistance or load-carrying ability.

In addition to giving proper performance from a viscosity standpoint, a transmission lubricant must also have other properties. One of these is oxidation resistance. This term defines the ability of a lubricant to resist the oxidation which might occur as a result of high temperature operation.

TABLE VII
SAE Viscosity Grade Classification, Transmission and Axle Lubricants

SAE Viscosity Grade Number	Viscosity (Saybolt Universal Seconds) at 0°F. Minimum	at 0°F. Maximum	at 210°F. Minimum	at 210°F. Maximum
75		15,000		
80	15,000	100,000		
or		100,000	48	
90			75	120
or		750,000	75	
140			120	200
250			200	



Courtesy of Ford Motor Company

Figure 16 — Typical differential with hypoid gearing: (1) pinion gear, (2) differential case, (3) ring gear, (4) differential side gear, (5) hypoid "offset".

While transmission temperatures normally will not be over 190-200°F, there are times when prolonged slow speed heavy pulling operation will cause the transmission lubricant temperature to exceed this value. While oxidation resistance is desirable under any circumstances it becomes extremely important at these higher temperatures.

As shown in Table VI, two general types of lubricants are recommended for use in manual transmissions. One type is the straight mineral gear oil which possesses no extreme pressure (EP) properties. These lubricants are recommended for the manual transmissions of the Corvair, Rambler and Lark. The Comet, Falcon and Valiant all recommend "hypoid" gear lubricants which do possess EP properties. In addition, it is recommended that these latter cars use only those hypoid gear lubricants which meet the requirements of API Gear Oil Classification GL-4. Since this type of lubricant is primarily intended for and used in the *differentials* of many cars, its properties and characteristics will be discussed in the section dealing with Differential Lubrication.

DIFFERENTIALS

Following a discussion of the engine and transmission, it is logical that the differential should be considered next since it is here that the engine torque, as modified by the transmission, is transferred to the axles and thus to the wheels. In considering this unit, no attempt will be made to discuss rear axle design since this will be covered under the section dealing with Rear Suspensions.

Since the rear wheels cannot be driven at engine speed nor can the engine develop sufficient torque at the speeds at which the rear wheels rotate, one of the major functions of the differential is to provide speed reduction with corresponding torque increase. The amount of speed reduction used is dependent on the size of the rear wheels and their rolling radius, the torque characteristics of the engine and the desired acceleration characteristics of the vehicle. As can be seen on Table V, this ratio varies with the car in question and ranges between 3.5 to 4.1 to 1. As indicated in Table V, the car manufacturer usually furnishes a lower rear axle ratio with cars equipped with automatic transmissions. This means that for every revolution of the rear wheels, the engine turns from 3.5 to 4.1 revolutions when the transmission is in high gear. This reduction is accomplished by coupling the engine, through the propeller shaft, to the pinion drive shaft of the differential unit as shown in Figure 16. The pinion drive shaft in turn drives the ring gear which drives the rear axles.

In most modern cars and in all of the compact cars, the centerline of the pinion drive shaft is lowered or offset below the centerline of the ring gear so that the propeller shaft housing will not intrude too far into the passenger space of the vehicle. This type of design is known as hypoid gearing. Figures 16 and 17 illustrate the hypoid design.

In addition to providing a speed reduction between the engine and the rear wheels, the differential also divides the driving torque between the rear wheels. Should one wheel lose or have less traction than the other wheel, it will partially slip or spin and thus provide a point of loss of the tractive effort. If complete spinning occurs, as on a patch of ice or snow, the other wheel will not move since all of the tractive effort is being dissipated through the spinning wheel. Aside from dividing the driving torque between the rear wheels, the differential also permits the outside wheel to roll faster than the inside wheel when rounding a corner. Under dry conditions and at moderate speeds, reasonably equal traction can be obtained on both wheels under these conditions.

Although not yet available on all compact cars, the Rambler and the Lark are supplied optionally with "limited slip" differential units which, when confronted with a situation where one wheel is tending to spin, automatically "lock-up" thus ap-

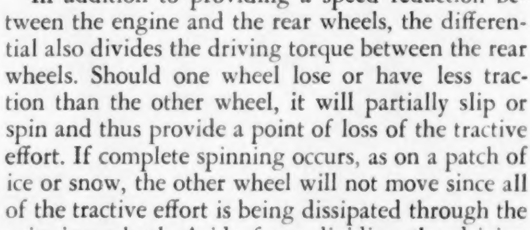


Figure 17 — Schematic view of hypoid and spiral bevel gearing showing relationship between pinion and ring gear in each configuration: (1) pinion gears, (2) ring gears.

plying the driving torque equally to both wheels as a unit. This locking-up is accomplished by the automatic engagement of small clutches within the differential unit which cause the wheels to turn together. When locked-up neither wheel can spin independently of the other. Since in snow, mud or on ice traction is usually lost on only one rear wheel at a time, such an arrangement materially improves the car's pulling power under slippery conditions.

As previously discussed in the section on transaxles, the Corvair differential is an integral part of the complete engine-transmission-differential unit as shown in Figures 14 and 15. The individual design features are generally conventional and the differential is fitted with hypoid gearing as are the other compact cars.

Differential Lubrication

The hypoid gearing used in all of the compact car differentials imposes certain stringent requirements on the lubricant by reason of its design. This type of gearing produces more sliding or rubbing motion between its teeth than normally occurs with spiral bevel gearing. In addition to the previously discussed lowering of the drive line, the advantages of this type of design are that hypoid gear teeth are very strong thus allowing the transmission of more power through the same size unit than would be possible if spiral bevel gears were used. Alternately, it permits the transmission of the same power through a smaller unit.

Because of the hypoid gear's unique tooth action, lubricants possessing exceptional properties are necessary to prevent scoring and welding of heavily-loaded hypoid gear teeth. As shown in Table VI, all of the compact cars use "hypoid" gear lubricants while the GL4 type of hypoid lubricant is recommended for the Corvair, Valiant and Lark. These are generally available throughout the country at all service stations. Their viscosities are defined by use of the SAE Gear Oil Viscosity Classification System which was discussed in the section dealing with Transmission Lubrication and shown in Table VII. It is extremely important that a lubricant of the correct viscosity be used and that, when necessary, the viscosity be changed to suit the expected average ambient temperatures. As discussed in the section dealing with Transmission Lubricants, an oil of suitable viscosity for low temperature operation may not be suitable for high temperature use due to excessive thinning. Conversely an oil which, due to its viscosity, was satisfactory for use under higher temperatures might not be suitable for extreme low temperature operation. Such an oil might fail to flow and thus cause the gears to run dry creating severe gear tooth damage.

While viscosity is an important factor, it has little bearing on other factors such as oxidation stability and load carrying ability. Due to the nature of the hypoid gear tooth action, high lubricant temperatures are generated. When a lubricant is constantly agitated in the presence of air and is also heated, oil oxidation can occur. Such oxidation can cause excessive thickening of the lubricant and under extreme conditions can cause the oil to solidify. For this reason, oxidation stability is an important quality of rear axle lubricants and high quality lubricants possess this property.

In addition to oxidation stability, hypoid gear lubricants must also possess high and rather special load carrying ability. As mentioned earlier, this property is imparted to the lubricant by the use of adequate amounts of special additives which prevent the welding and scoring of the gear teeth.

The hypoid lubricant designation of GL-4 was established by the API to define a type of gear service in which certain lubricants would be suitable. A product defined as a GL-4 type of lubricant will, in the refiner's opinion, perform satisfactorily under the service conditions defined by the API as follows:

"This term (GL-4) designates lubricants which have the properties required to provide satisfactory lubrication of hypoid gears and conventional differentials including adequate load carrying ability for protection of such gears in sustained high speed and/or torque service in modern high powered passenger cars and trucks. They are suitable for use in spiral-bevel gears, many transmissions, and for worm gears in some types of service. Such lubricants are identified as meeting API Service GL-4".

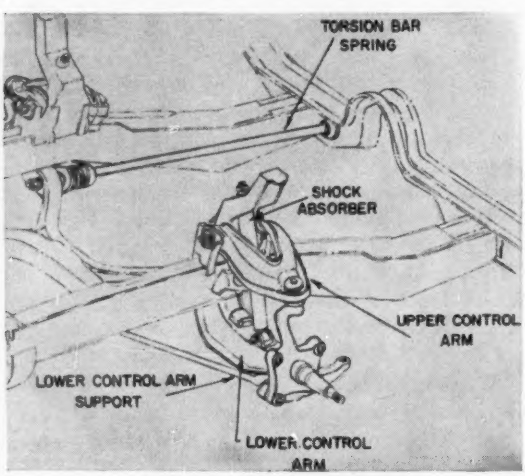
In addition to the above classification, many petroleum producers also make available through their service stations, oils which meet the stringent performance requirements of Interim Military Specification MIL-L-002105A. This specification was established by the Department of the Army to define in precise terms the performance characteristics desired in hypoid gear lubricants for modern heavy duty military equipment. To meet and be qualified against this specification a gear lubricant must demonstrate outstanding oxidation stability, good rust protection and high load carrying ability when subjected to a series of stringent performance tests. Whether or not a lubricant is actually qualified under this specification is not usually mentioned on lubricant containers in deference to governmental policy.

When a differential incorporates the "limited slip" feature, special lubricants are occasionally necessary to prevent "chatter" when making short radius turns under power. Since the limited slip differential is unable to distinguish whether the unequal wheel velocities it notices come from rounding a turn or from the spinning of one wheel on ice,

Courtesy of Studebaker-Packard Corporation

Figure 18 — Lark front suspension: (1) upper control arm, (2) coil spring, (3) shock absorber, (4) lower control arm.

it tends to "lock-up" under any circumstances when unequal velocities are noted and power is being applied. However, when the differential clutches are engaged under the "locked-up" circumstance discussed above, and the rear wheels are rounding a corner on dry pavement, slippage must occur at



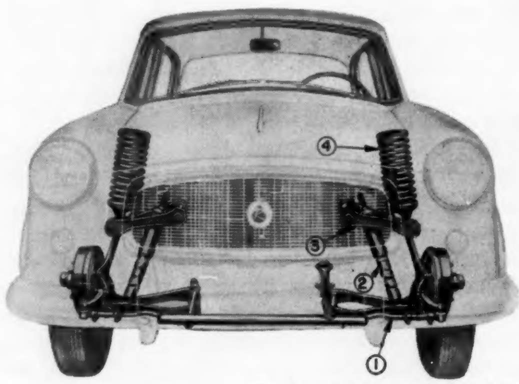
Courtesy of Chrysler Corporation

Figure 20 — Chrysler Valiant front suspension showing major structural members.

some point. Some slippage occurs at the point where the rear tires contact the road but more occurs in the differential locking clutches which then tend to chatter. While this is not a universal condition, it does exist in some limited slip differentials depending on their specific design and the resonant vibration characteristics of the axle shafts, the axle housing and the propeller shaft and the lubricant used. For this reason and as indicated in Table VI special lubricants are recommended for use in some cars equipped with "limited slip" differentials.

SUSPENSION SYSTEMS

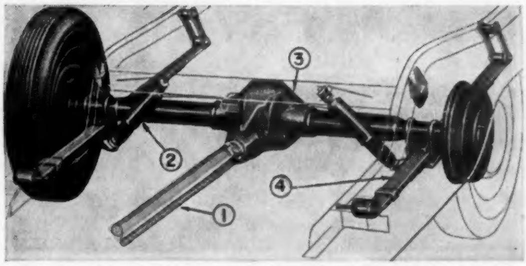
Before discussing the particular features of the various compact car suspensions it might be well to orient the reader as to what suspension systems are designed to do. First of all it must be recognized that unless the tires are kept in contact with the road, no movement or change in velocity or direction of the vehicle is possible. This is an essential point since it is through these contact points that all the forces used for acceleration, cornering, directional control and braking of the vehicle are applied to the road surface or to the vehicle. Thus the primary purpose of the entire suspension system is



Courtesy of American Motors Corp.

Figure 19 — Rambler front suspension: (1) lower control arm, (2) shock absorber, (3) upper control arm, (4) spring.

to maintain the contact between the tire and the road and to provide maximum passenger comfort consistent with vehicle safety. Specifically, contact is maintained by transferring the body weight through springs to the wheels and ultimately to the road. That portion of the suspension system, which transmits this force to the road and oscillates up and down with road irregularities is called the "unsprung weight". The amount of the wheel movement or "bounce" obtained as a result of striking a bump is affected by tire characteristics and is proportional to the unsprung weight and inversely proportional to the spring "rate" or spring stiffness.



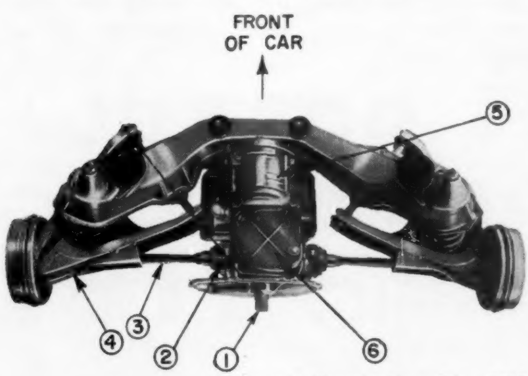
Courtesy of Ford Motor Company

Figure 21 — Ford Falcon rear suspension: (1) propeller shaft, (2) shock absorber, (3) differential housing, (4) Semi Eliptic left rear spring.

To assure that such wheel motions are not prolonged, their movements are retarded and modified by a shock absorber. Ideally if the unsprung weight or mass could be reduced to zero, wheel contact and passenger comfort would be assured. Practically this is not possible since the structural members, wheels and tires do have an irreducible minimum weight. Other factors which affect wheel movements are tire pressure, shock absorber damping rates, spring rates and the resilience of the tire casings and treads. All of these factors have to be resolved and integrated into the basic vehicle design together with additional considerations such as the weight distribution and weight transference during braking or acceleration. As a result of considerable compromise, all of these factors are resolved and the final physical features of the suspension are evolved.

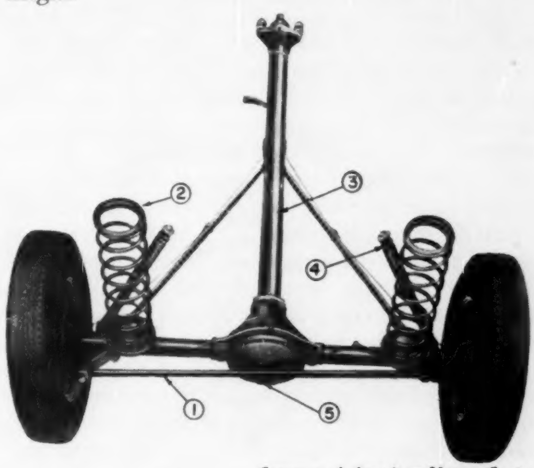
Front Suspension Systems

The front suspension systems of all of the compact cars are independent. This is to say that either front wheel can respond to a bump or road irregularity independently of the other. A typical suspension of this type is found in Figure 18. Since most of the compact cars are relatively light, some designers have placed the front spring over the suspension members in order that lower spring rates could be used. This type of arrangement is used in the Falcon, Comet and Rambler and is shown in Figure 19. The Valiant does not use a coil spring but rather a torsion bar suspension as shown in Figure 20. This has certain advantages in that it further reduces the unsprung weight. In a normal coil spring arrangement, the portion of the spring which oscillates with the suspension is regarded as part of the unsprung weight. In addition, the use of a torsion bar permits the front suspension height to be adjusted. Should a coil spring "sag", complete replacement of the spring is necessary. With a torsion bar, a slight adjustment will restore the normal vehicle height.



Courtesy of Chevrolet Motor Div., GMC

Figure 23 — Chevrolet Corvair rear suspension: (1) transmission drive shaft, (2) universal joint, (3) left axle shaft, (4) left rear wheel mount, (5) automatic transmission (6) differential.



Courtesy of American Motors Corp.

Figure 22 — Rambler rear suspension showing torque tube drive: (1) panhard rod, (2) coil spring, (3) torque tube, (4) shock absorber, (5) differential housing.

All but a few of the front suspension systems use ball joints to connect the major suspension components and some use two of these to replace the four cylindrical plain bearings (or antifriction bearings) in the conventional front wheel king pin. This type of connector is shown at the outer end of the upper control arm in Figure 20.

Rear Suspension Systems

All of the compact cars except the Corvair have so-called "live" or "unit" rear axles wherein the axle shafts, wheel bearings and the differential are entirely encased in one housing, all of which is unsprung weight. As can be imagined, the weight of the rear axle assembly is rather high; however, on the generally smooth American roads, handling characteristics are not unduly impaired with this arrangement.

All of the live rear axle housings used in the

compacts except the Rambler are of the "Hotchkiss" drive type. In this arrangement, shown in Figure 21, the torque reactions created when accelerating or braking the vehicle are carried by the rear springs which are of the semi-eliptic type. The propeller shaft is open and is attached by means of universal joints to the transmission and differential. Rear axle vibrations created by rough road surfaces are thus isolated in the rear of the vehicle.

The Rambler uses the "torque tube" type of drive shown in Figure 22 wherein the braking and accelerating forces are absorbed by means of a long tube which surrounds the propeller shaft. In this design coil springs can be used for the rear suspensions since the springs are not a structural part of the suspension and a "Panhard rod" is used to transversely locate the axle assembly.

The Corvair employs rear "swing axles" and is the only American car to have independent suspension of the rear wheels. This arrangement is rather interesting in that it is a somewhat radical departure from the usual independent rear wheel suspensions normally used in European cars. As shown in Figure 23, each of the wheels is mounted on a supporting member. This supporting member is attached to the chassis of the car in such a manner that a line drawn through its pivot point passes through the center of the axle drive universal joints. This arrangement eliminates the necessity of having sliding splines on each axle shaft since there is no need to adjust for a change in the length of the axles as a result of wheel deflections. This results in less complication with a resultant saving in production costs. Because of their decrease in unsprung weight, the riding characteristics of independent rear wheel suspension systems are generally better on rough roads than when a "live" axle is used.

Suspension and Chassis Lubrication

All of the suspension systems include points which must be periodically lubricated. This is particularly true of the ball joint units used to connect the front suspension system components. Unfortunately suspension and chassis lubrication points are usually the ones which receive the least attention. This is probably due to the fact that the supply of lubricant at any one chassis lubricating point is not subject to periodic inspection as is the engine oil. Thus, when the supply of lubricant is depleted and serious wear begins to develop in chassis components, the average driver is usually not aware of the fact. Eventually the wear will reach the point where a costly repair bill is necessary to replace the worn parts. For this reason it is extremely important that the chassis be lubricated at periodic intervals.

The properties desired in chassis lubricants are easily envisioned. First of all such grease must have the necessary characteristics to support the loads imposed and thus prevent excessive wear. This is sometimes difficult since many of the parts to be lubricated move at relatively slow speed with relation to each other and thus do not bring large quantities of new lubricant to the working area. For this reason it is essential that a chassis grease possess the ability to remain within the working area and not be squeezed out even under extreme load conditions. They must be shear stable or in other words be able to work for prolonged periods without thinning and running out of the fitting. Chassis lubricants must also help to exclude water from the part so as to reduce the possibility of rusting. In so doing they must also resist washing out by the water. Finally they must prevent the formation of rust should water be present.

Until recently, *oscillating* chassis bearings and *rotating* wheel bearings required two separate lubricants: a chassis grease available in a heavy summer and lighter winter grades: and a single year-around grade of a highly specialized wheel bearing grease. While it was possible (though not necessarily economic) to use a wheel bearing grease in most chassis bearings, any attempt to use a conventional chassis grease in modern wheel bearings was fraught with danger since the chassis lubricant might liquefy and flow out onto brake linings.

Now, however, good "multipurpose" greases are available which are widely and most conveniently used to lubricate both chassis and wheel bearings, water pumps and numerous other lubrication points.

All of the compact cars may have optional-equipment accessories which may require lubrication. However, the variety and occasionally specialized nature of these requirements precludes their discussion at this time.

SUMMARY

The compact cars are becoming an increasing factor on the American automotive scene. Their many excellent engineering features are being widely accepted by the automotive public. Fuel and lubrication requirements are not unusual and can be met by those normally available at most reputable service stations.

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